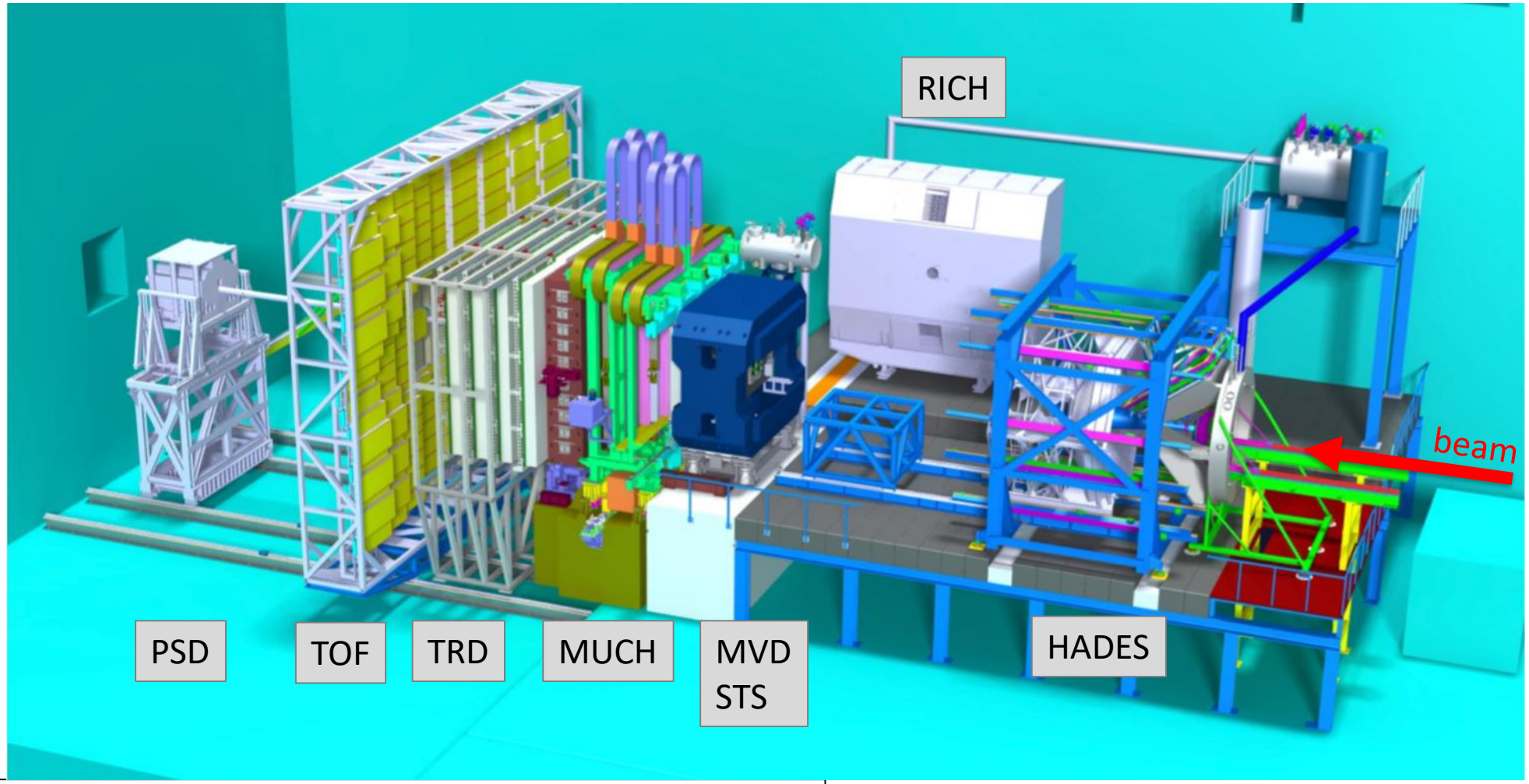
CBM status experiments



Outline: Day-1 setup CBM (> 2024)
FAIR phase 0 program (2018 – 2024)
HADES mCBM

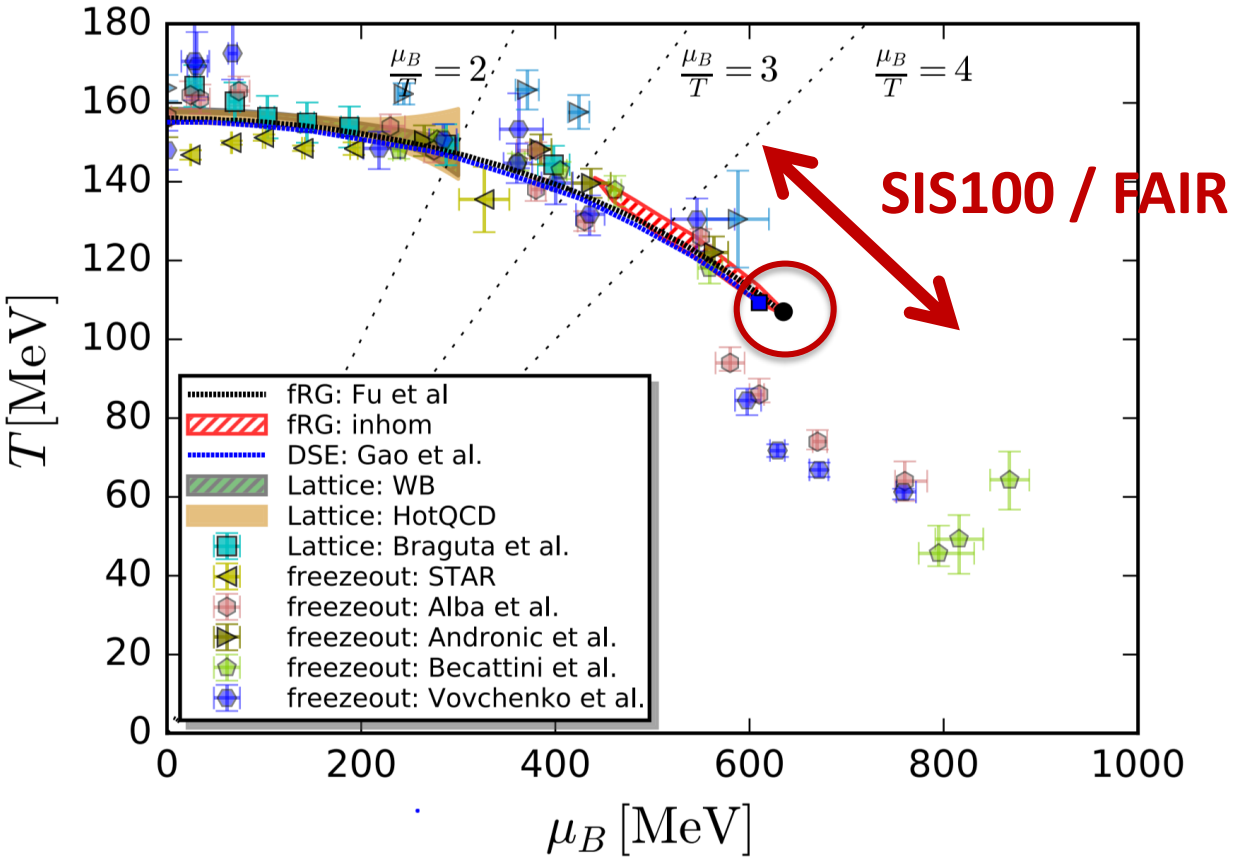
CBM building

Impressive progress in civil construction

Theoretical Progress: Status of Critical End Point

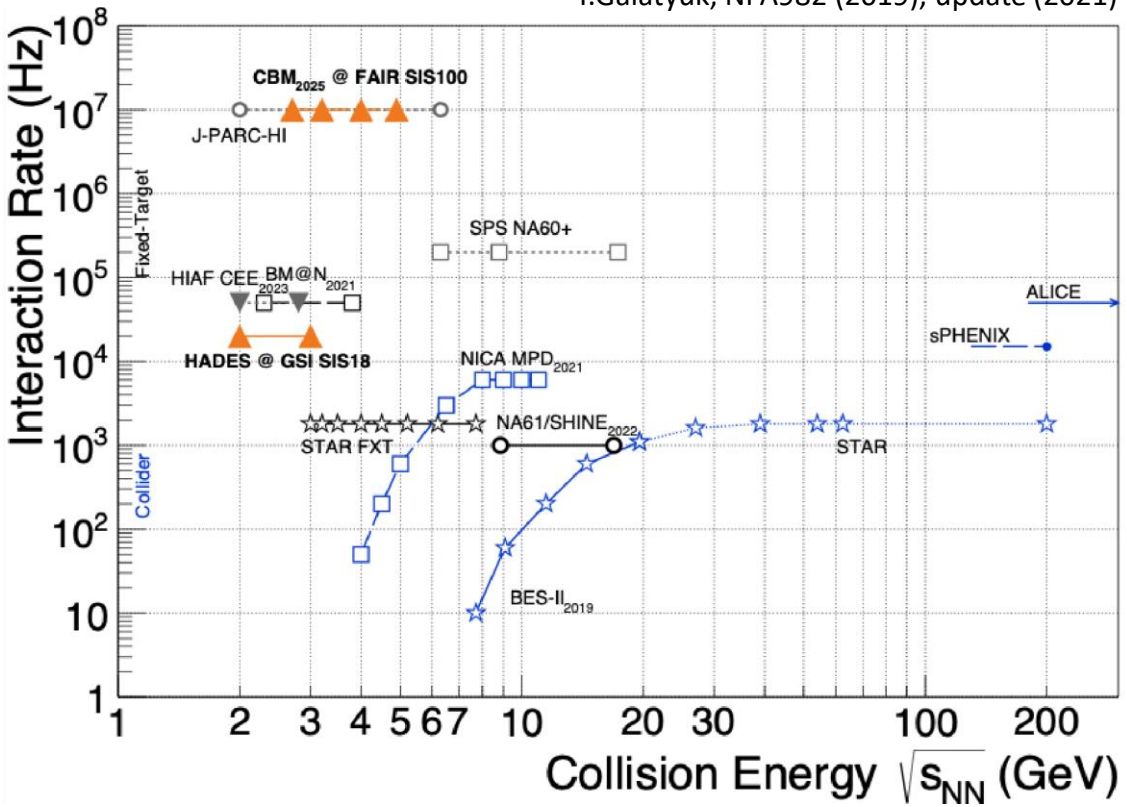
W. Fu, J. Pawlowski, F. Rennecke, *Phys.Rev.D* 101 (2020) 5, 054032, arXiv:1909.02991

Location of chiral cross over



(T_{cep}, $\mu_{B,cep}$) = (107, 635) MeV
$\sqrt{s_{NN}}$ = 3.7 GeV
E_{kin} = 5 GeV/u

CBM Collaboration, EPJA 53 3 (2017) 60
T.Galatyuk, NPA982 (2019), update (2021)



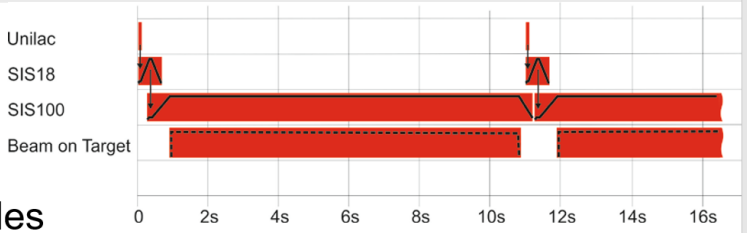
CBM - Mission:
Systematically explore QCD matter at large baryon densities with high accuracy and rare probes.

CBM Physics with Project Completion Parameters (PCP)

CBM: Parameters and configuration for possible first impactful physics

SIS100 slow extraction (10 s) from 4 - 10 GeV/u
Di-electron program with day-1 configuration:

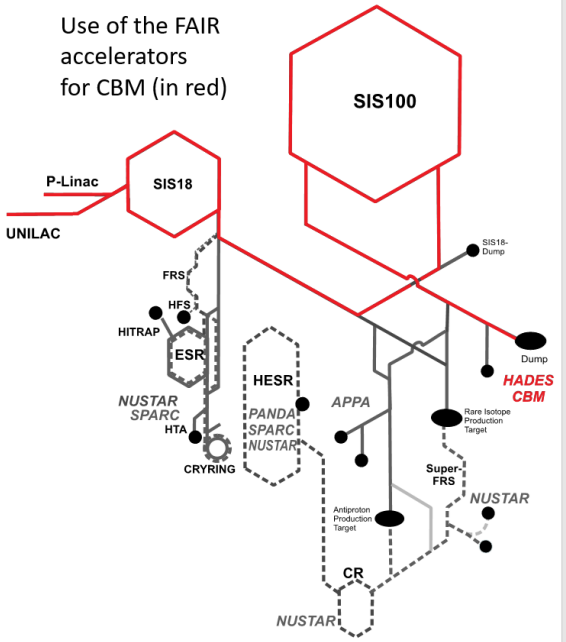
Au^{79+}: 1E8 / 10s spill (1E7/s)



Full physics potential for di-electron observables

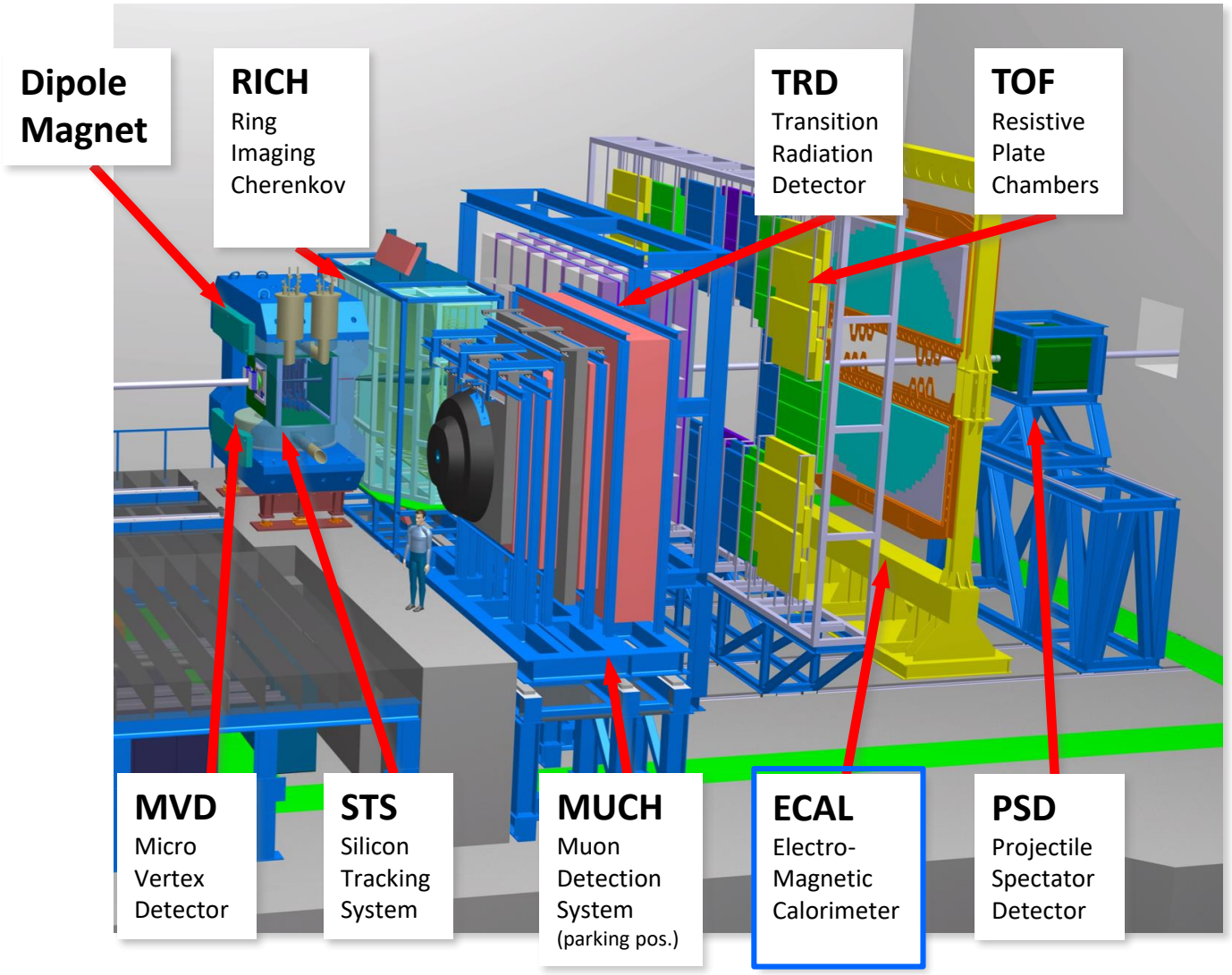
- Excitation function measurements of slope in IMR region require ~4 weeks beam time per beam energy

CBM Experiment requirements											
Beam Parameters	Ion type										
	p	^{40}Ar	^{58}Ni	^{107}Ag	^{197}Au	p	^{14}N	^{40}Ar	^{58}Ni	^{107}Ag	^{197}Au
	Commissioning					Operation in MSV					
Time structure	slow extraction										
Spill length [s]	5	10				5	10				
Number of ions per cycle	10^{10}	$4x10^8$		$2x10^8$	10^8	10^{12}	10^{11}	$4x10^{10}$		$2x10^{10}$	10^{10}
Energy range [GeV/u]	5-11, 14-29	3-11	2-11			5-11, 14-29	3-11	2-11			
Ref. energy [GeV/u]	29	11				29	11				
Transverse emittance (4σ) [mm mrad]	1 x 0.6										
Momentum spread (2σ)	5×10^{-4}										
Beam spot radius on target [mm]	1										



- SIS100 beam requirements are being updated
- PCP unchanged
- Matches CBM day-1 configuration
- Achievable Au+Au interaction rate limited by rate capability of MVD detector to 100 kHz (1E7/s beam particles)

CBM experimental setup (day-1)



- Tracking acceptance:
  $2^o < \theta_{lab} < 25^o$
- Free streaming DAQ
- R_{int} = 10 MHz (Au+Au)

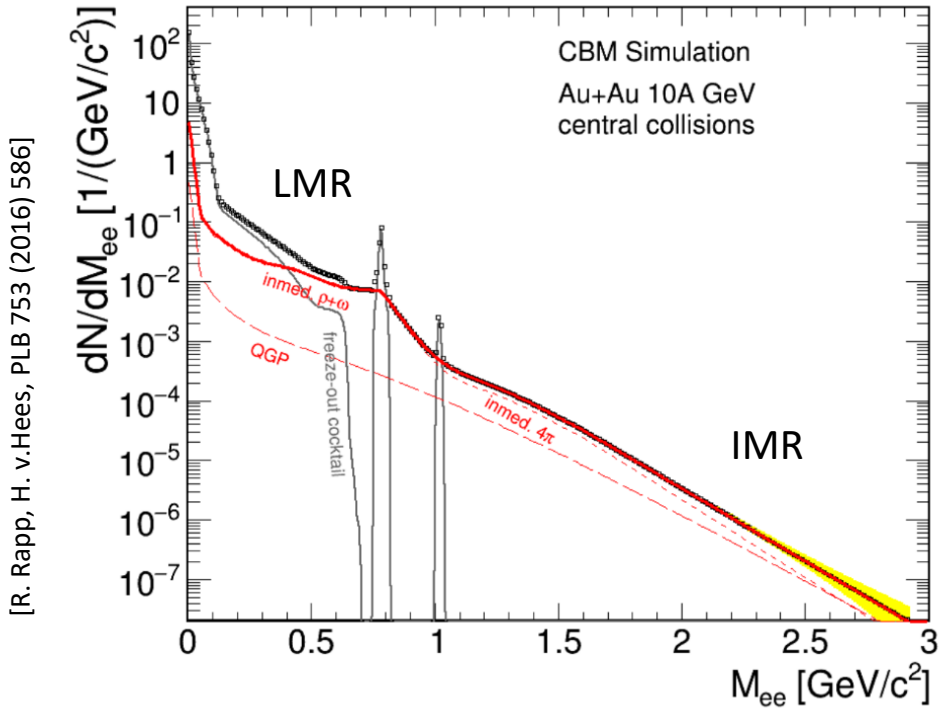
  $R_{int} \approx 0.5$ MHz
  full bandwith:
  Det. – Entry nodes
  reduced bandwidth
  Entry nodes – Comp. farm

  with
  R_{int} (MVD)=0.1 MHz
- Software based event selection

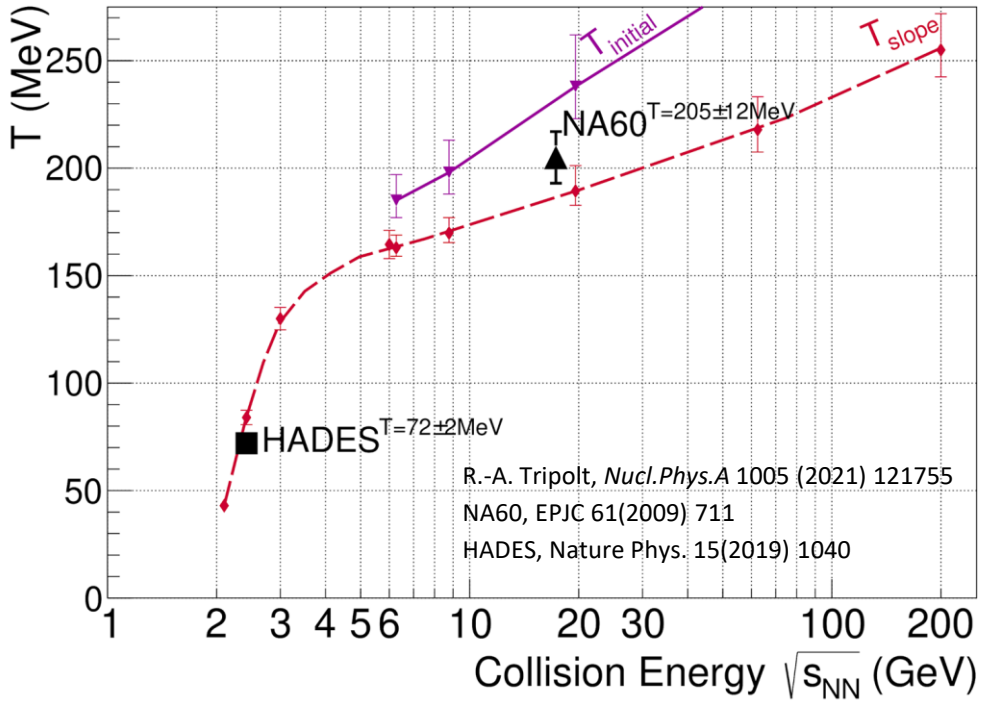
Day-1 funding:
~ 90% secured

Day-1 setup = MSV setup – Compute Performance - ECAL

Dileptons as probes for dense matter (Day-1)



[R. Rapp, H. v.Hees, PLB 753 (2016) 586]



LMR: ρ – chiral symmetry restoration
fireball space – time extension

IMR: access to fireball temperature
ρ-a_1 chiral mixing

Measurement program:

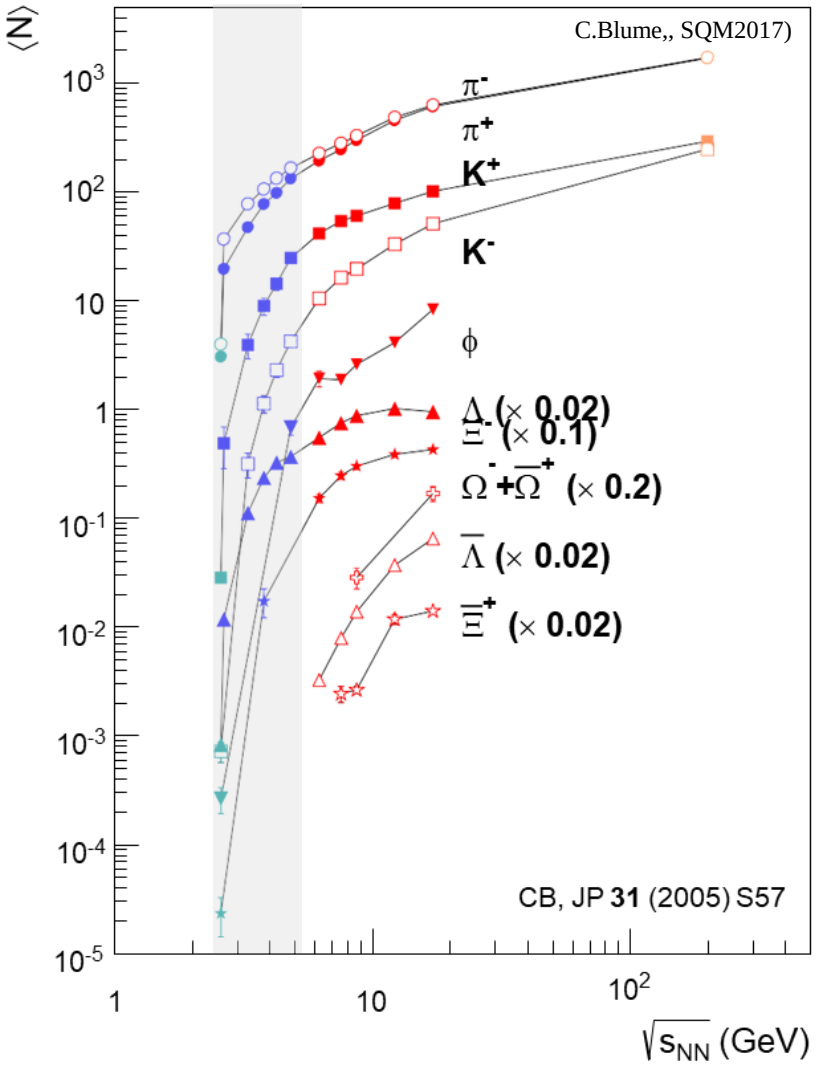
- excitation function of LMR – excess
- excitation function of IMR – slope (caloric curve)
  (~20 days of data taking needed for 1 data point)

Sensitivity to phase transition:

non – monotonic behavior of T_{slope}

Strange hadrons as probes for dense matter (day-1)

World data, central Au + Au collisions

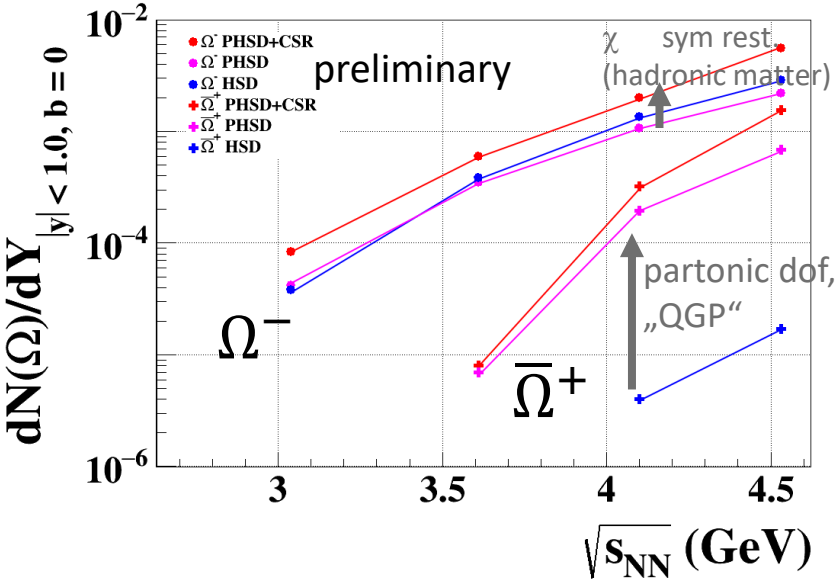


Strange and charmed particle production thresholds in pp - collisions

reaction	$\sqrt{s}$ (GeV)	T_{lab}(GeV)
$pp \rightarrow K^+\Lambda p$	2.548	1.6
$pp \rightarrow K^+K^-pp$	2.864	2.5
$pp \rightarrow K^+K^+\Xi^-p$	3.247	3.7
$pp \rightarrow K^+K^+K^+\Omega^-n$	4.092	7.0
$pp \rightarrow \Lambda\bar{\Lambda}pp$	4.108	7.1
$pp \rightarrow \Xi^-\bar{\Xi}^+pp$	4.520	9.0
$pp \rightarrow \Omega^-\bar{\Omega}^+pp$	5.222	12.7
$pp \rightarrow J/\Psi\, pp$	4.973	12.2

Transport Model Predictions

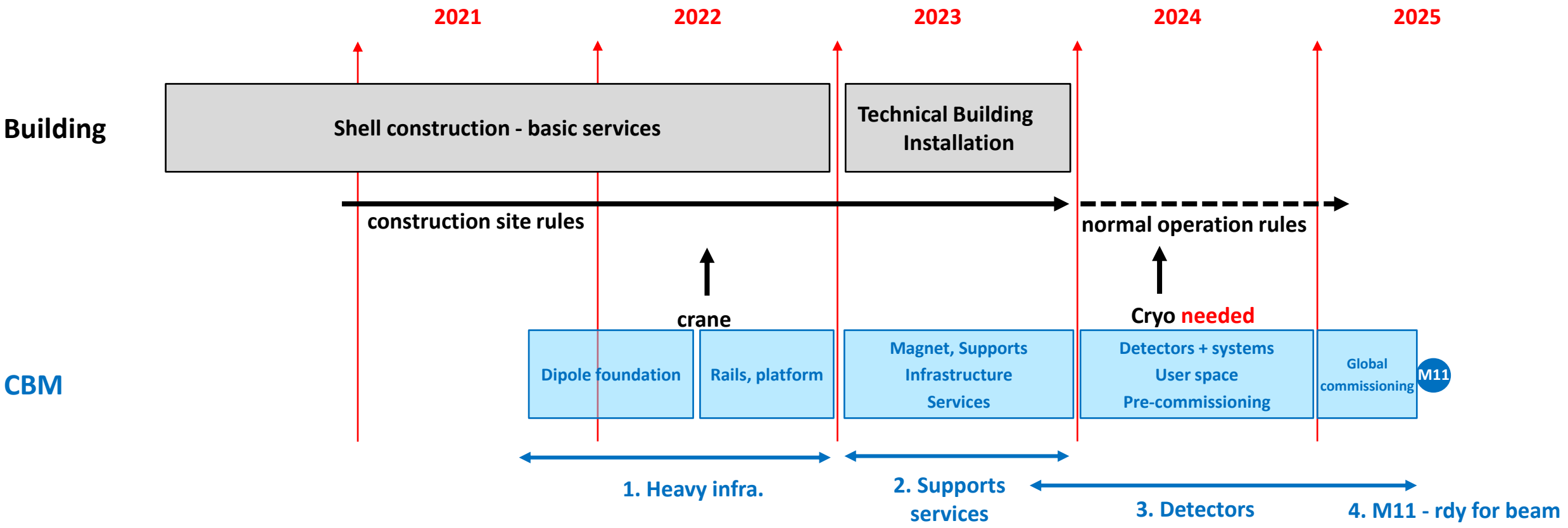
PHSD W. Cassing, E. Bratkovskaya et al., Phys.Rev. C93 (2016), 014902
I. Vassiliev, CBM Prog.Report 2019



Sensitivities of subthreshold particle production

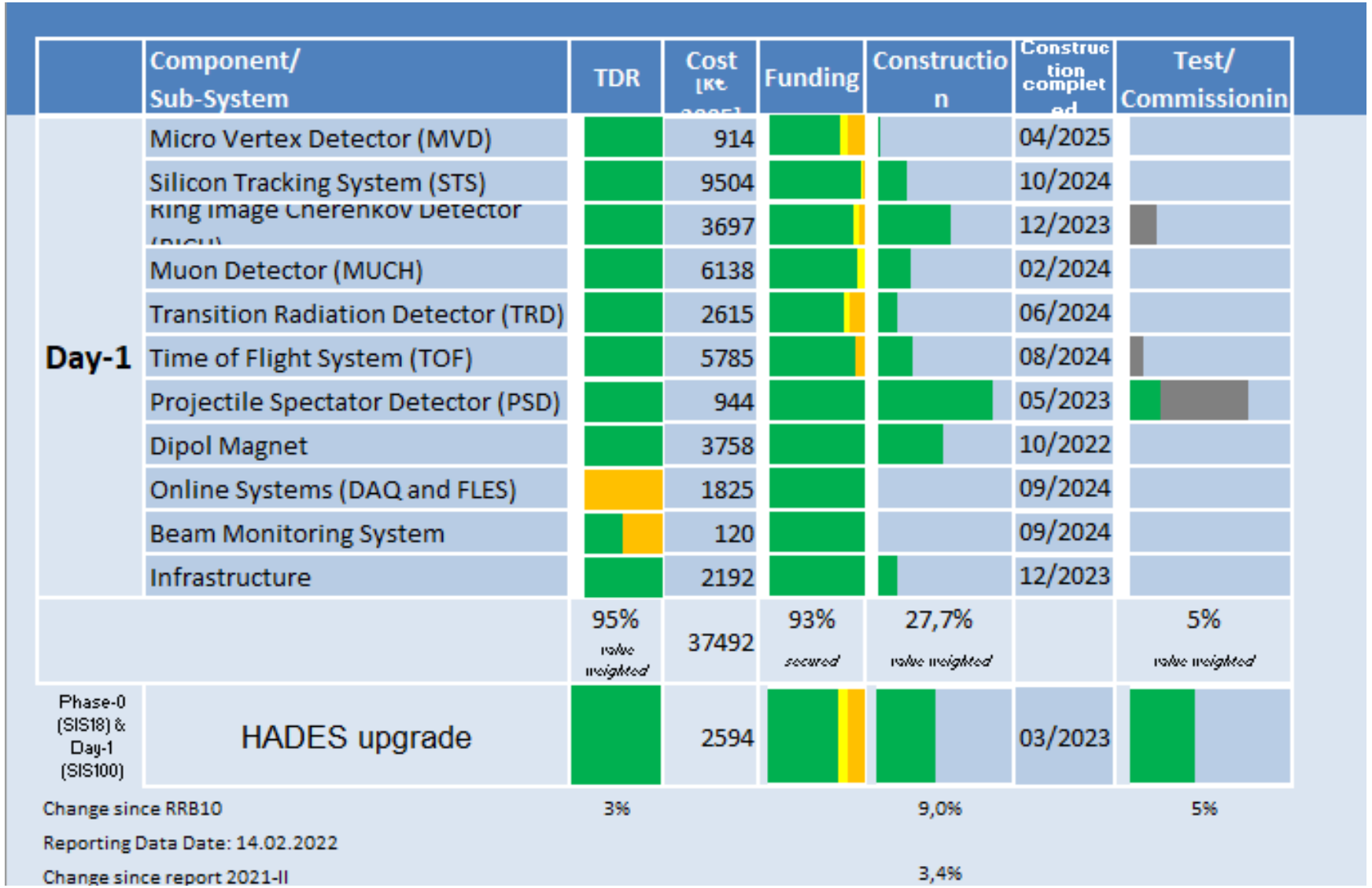
- Equation-of-state
- In-medium properties of hadrons
- Contributions from partonic degrees of freedom („QGP“)

CBM installation – baseline 2021



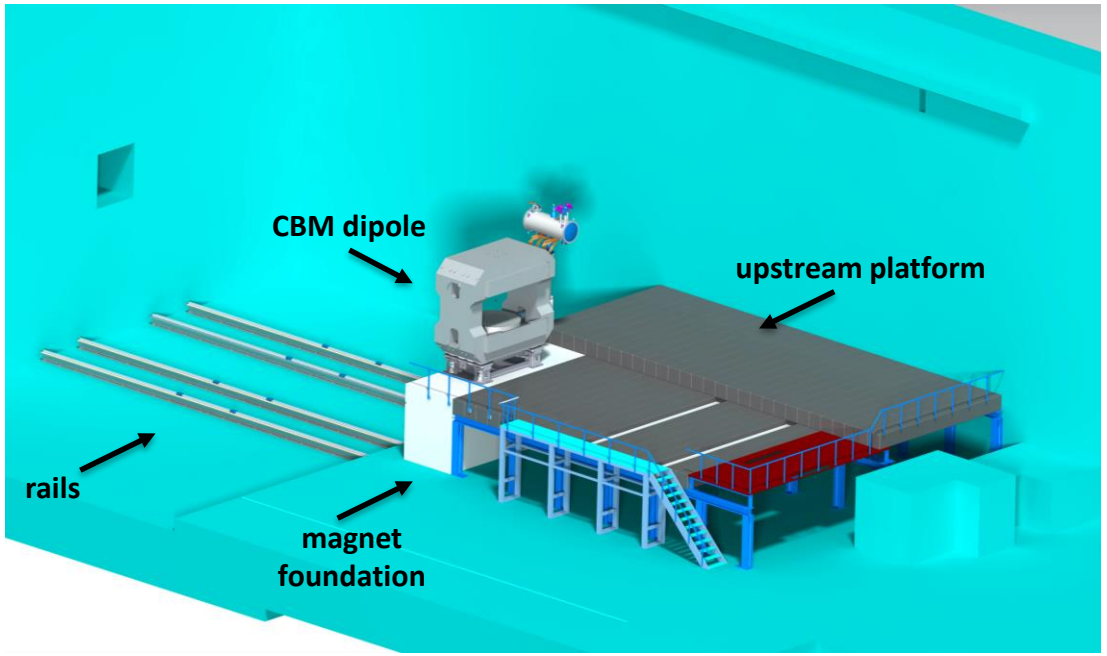
- Planning aims at Day-1 setup “Ready for beam” in mid 2025
- Success depends on availability of services, like crane,cryo, power, cooling, … provided by FAIR.

C.B.M. status – Score Card



	Component/ Sub-System	TDR	Cost [k€ 2025]	Funding	Construction	Construction completed	Test/ Commissioning
Day-1	Micro Vertex Detector (MVD)		914			04/2025	
	Silicon Tracking System (STS)		9504			10/2024	
	Ring Image Cherenkov Detector (RICH)		3697			12/2023	
	Muon Detector (MUCH)		6138			02/2024	
	Transition Radiation Detector (TRD)		2615			06/2024	
	Time of Flight System (TOF)		5785			08/2024	
	Projectile Spectator Detector (PSD)		944			05/2023	
	Dipol Magnet		3758			10/2022	
	Online Systems (DAQ and FLES)		1825			09/2024	
	Beam Monitoring System		120			09/2024	
	Infrastructure		2192			12/2023	
		95% value weighted	37492	93% secured	27,7% value weighted		5% value weighted
Phase-0 (SIS18) & Day-1 (SIS100)	HADES upgrade		2594			03/2023	
Change since RRB10		3%			9,0%		5%
Reporting Data Date: 14.02.2022							
Change since report 2021-II					3,4%		

Cave infrastructure



CBM Collaboration Memorandum of Understanding 15.04.2020

Memorandum of Understanding

for Collaboration in the Construction of the Compressed Baryonic Matter (CBM) Experiment at FAIR

between

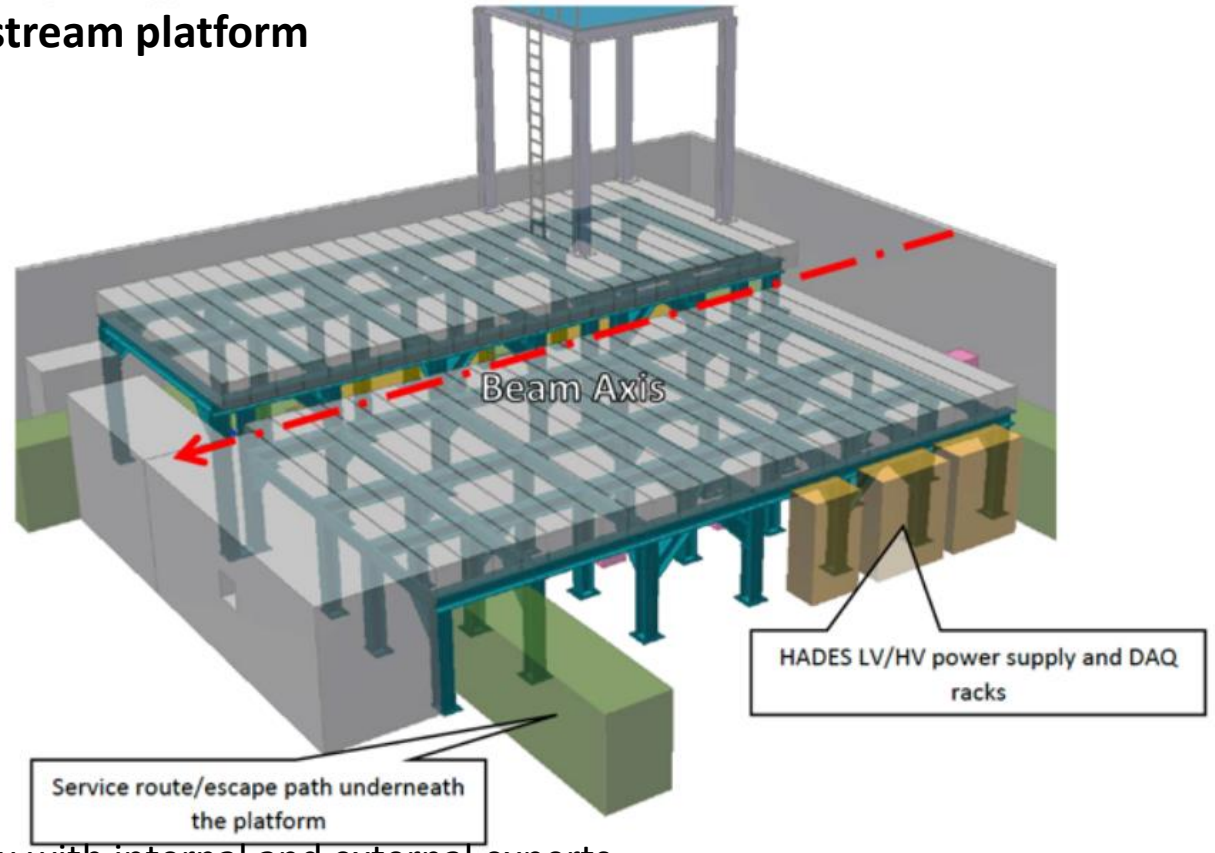
the Facility for Antiproton and Ion Research in Europe GmbH, hereinafter referred to as FAIR GmbH,

and

the full member institutions of the CBM Collaboration (hereinafter referred to as *Member Institutions*)

together with the corresponding funding agencies

Upstream platform



Timeline:

Dec. 2021: Conceptual design review with internal and external experts
(incl. Lange + Ewald Ingenieure GmbH, the contracted company from Darmstadt).
Feb. 2022: Updated CDR received. Design model frozen. Start working on detailed, certified structure calcs.
Mar. 2022: FDR (Final Design Review) + production drawings.
April 2022: Tender (in Czechia)
May-Nov. 2022: Production
Nov.-Dec. 2022: Installation (urgent due to money flow constraints)

Magnet

Magnet (GSI, BINP Novosibirsk, JINR Dubna)

Main achievements since Nov. 2021

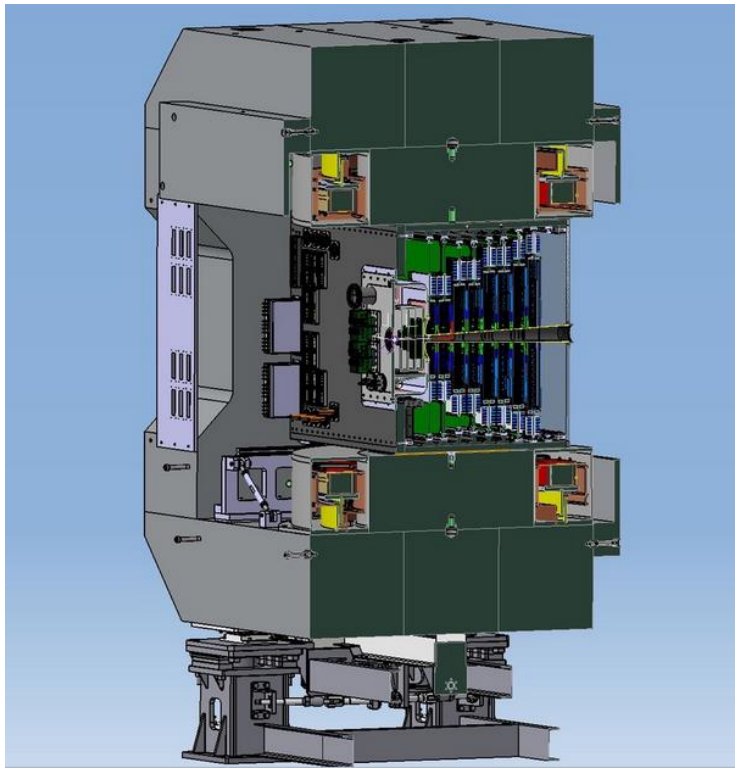
- Yoke produced and assembled (without pole shoes)
- Yoke support production ongoing
- Production of Power Supply and Energy Extract. Syst. in progress

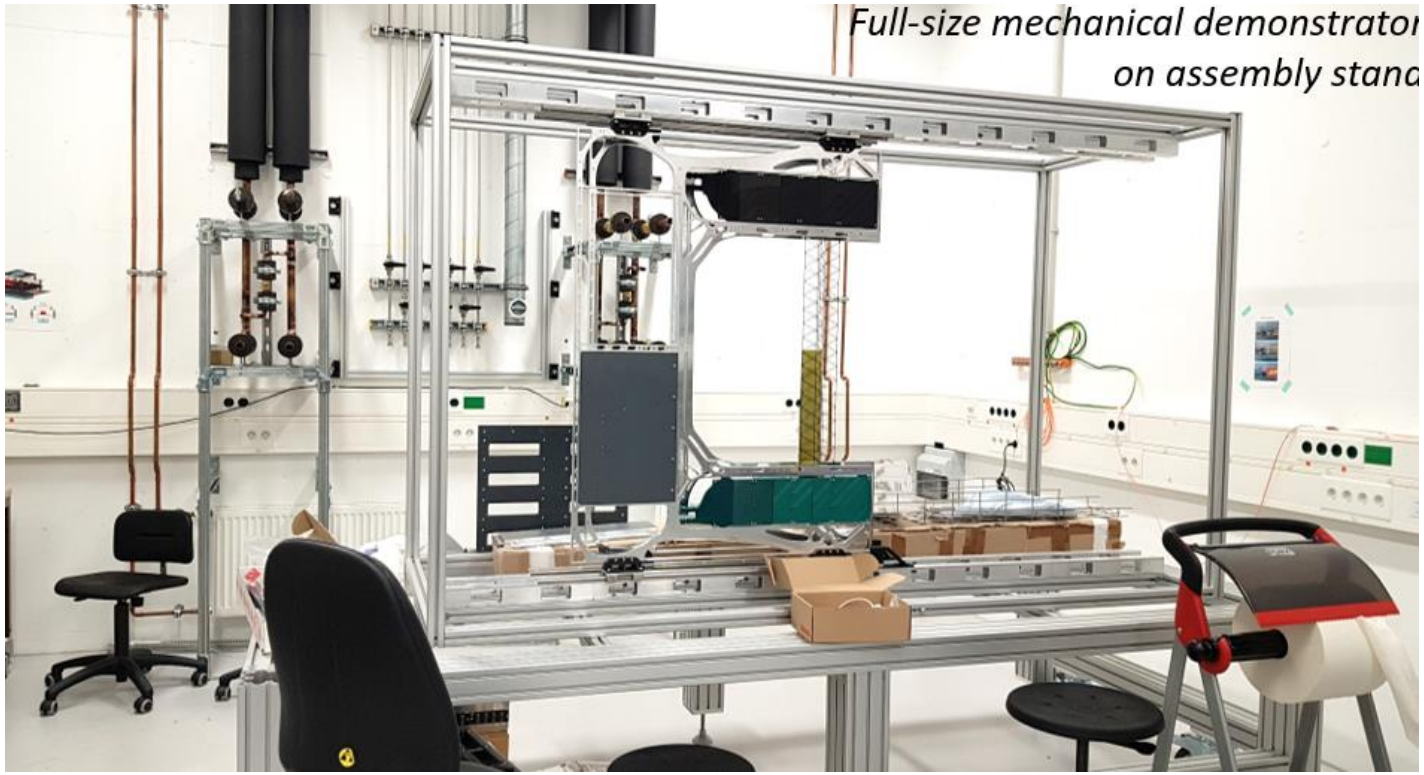
Essential steps in next months

- FDR of the cryogenic system in spring 2022
  - Priority design cryostat (still some open questions),
  - Design of branch box and transfer line almost final
- FDR coil in spring 2022:
  - Impregnation tests with a realistic mockup delayed, new date End of February 2022
  - Single ring support strut (GFRP): Calculations ok (some material properties under discussion)
  - Stability test with a 1000 t press performed, to be evaluated
- Magnet control system: responsibilities and interfaces to be defined

STS

STS (GSI Darmstadt, JINR Dubna, KIT Karlsruhe, JU Crakow, AGH Crakov, KINR Kiev, Univ. Tübingen, Warsaw UT)





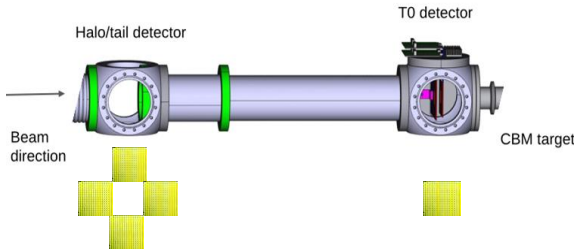
Preparation of pre-series production and PRR:

- EDR STS Mechanics (5 Nov. 2021) successfully concluded
- FEB8-2v3: pilot production, delivery delayed Dec. 2021 -> Feb. 2022
- FEB8-5v3:
  - var. A design finished (JU+GSI). Ordered GSI in China. End Feb. 2022.
  - var. B to be derived from variant A. Delivery target March 2022, t.b.c.
- FEB8-5v3 read-out cable, producer LTU, ordered (GSI): Mid Feb. 2022.
- STS-XYTER v2.2 series production, order placed through AGH

Status of detector projects

BMON (GSI, TU Darmstadt)

- BMON detector concept for CBM Day 1: two stations for HALO and T0 measurement
- Start detector concept for Day-1 based on pcCVD high purity diamond sensors
- New offers of pcCVD diamond material from Element Six
- R&D beamtimes on new sensor materials (COSY@Jülich, mCBM@GSI, S-DALINAC@TU Darmstadt)



MVD (U Frankfurt, GSI, IKF Frankfurt, IPHC Strasbourg, Pusan Nat'l Univ.)

- TDR accepted by ECE in 10/2021
- MIMOSIS-1 analysis ongoing
- MIMOSIS-2 submission (PRR in January 2/2022)
- Integration activites hampered by funding decisions → mitigation ongoing

MUCH (Aligarh Muslim Univ., Bose Inst. Kolkata, Panjab Univ., Univ. of Jammu. , Univ. of Kashmir, Univ. of Calcutta, B.H. Univ. Varanasi, VECC Kolkata, IOP Bhubaneswar, NISER Bhubaneswar, IIT Kharagpur, IIT Indore, Gauhati Univ., PNPI Gatchina)

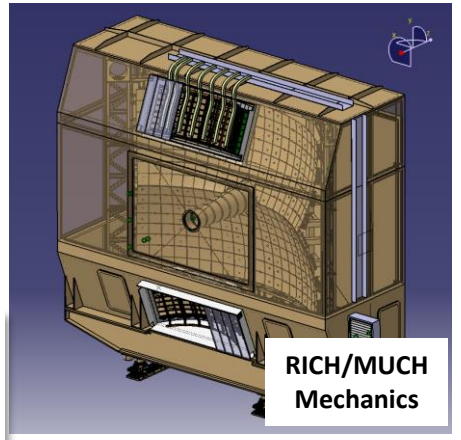
- Built and tested the first GEM chamber for the 2nd station of MuCh
- Assembled and tested the real size RPC for the 3rd station of MuCh
- First HV supply crate assembled at VECC and tested with GEM
- CDR reviews completed: MuCh gas system, GEM chambers, chamber mechanics

MUCH GEM at GIF++ (Nov.21)

Status of detector projects

RICH (Univ. Giessen, Univ. Wuppertal, PNPI Gatchina, GSI Darmstadt)

- RICH mechanical design (PNPI) close to final
- Readout electronics – first of series FOS
- DIRICH frontend module tested up to 300 kHz/pixel (CBM full rate), no performance issues
- RICH photon camera design finalized
- First steps and prototypes towards RICH DCS and interlocks



RICH/MUCH Mechanics

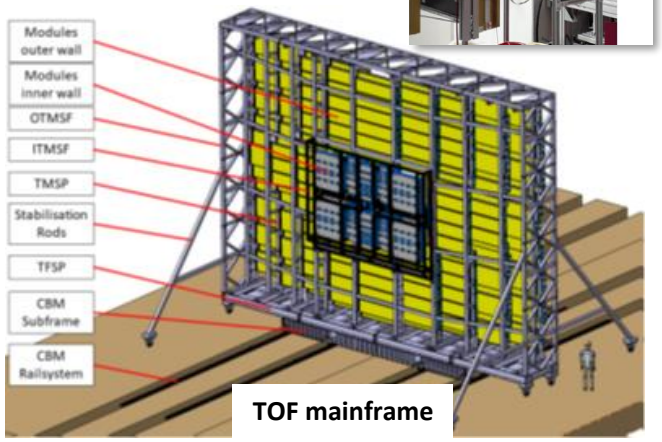
TRD (NIPNE Bucharest, Univ. Frankfurt, Univ. Heidelberg, Univ. Münster,IRI Frankfurt)

- Addendum to TRD TDR for TRD2D submitted to ECE
- Successful CRI-based data taking with SPADIC and FASP based readout
- Tests of SPADIC 2.3a started

TRD prototypes n mCBM

TOF (THU Beijing, NIPNE Bucharest, GSI Darmstadt, TU Darmstadt, USTC Hefei, Univ. Heidelberg, ITEP Moscow, HZDR Rossendorf, CCNU Wuhan)

- Mitigation for observed aging ongoing, several sealed counter constructed and tested
- Preparation of mCBM high rate running 2022
- Main frame CDR passed
- Gas system under development (new partner in Romania) (not financed)



TOF mainframe

PSD (INR Moscow, TU Darmstadt, CTU Prague, NPI Rez)

- All modules produced, upper support structure arrived at FAIR in 09.2020
- Commissioning of the FHCal at the BM@N during SRC run at the BM@N – Feb. 2022.
- Start of ordering and purchase of the PSD FEE and readout electronics.

PSD at BM@N

FAIR Phase-0 Program

- HADES production beam times
- mCBM development beam times

HADES Phase-0 activities

S477 March 2019 (Ag+Ag)

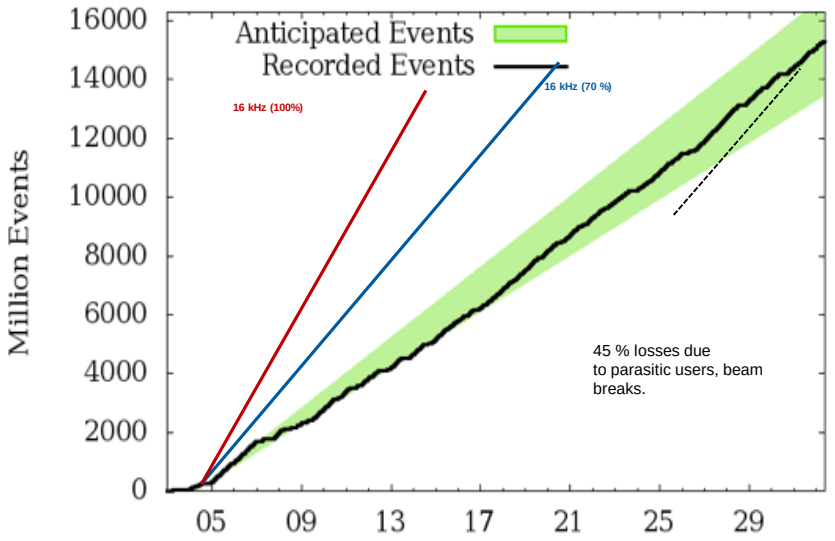
- 15 B events taken in four weeks
- New detectors: RICH photon camera (CBM) and ECAL (HADES)
- Event reconstruction finished, first publications in preparation
- 13 PhD students on physics analysis (first publications in 2022)

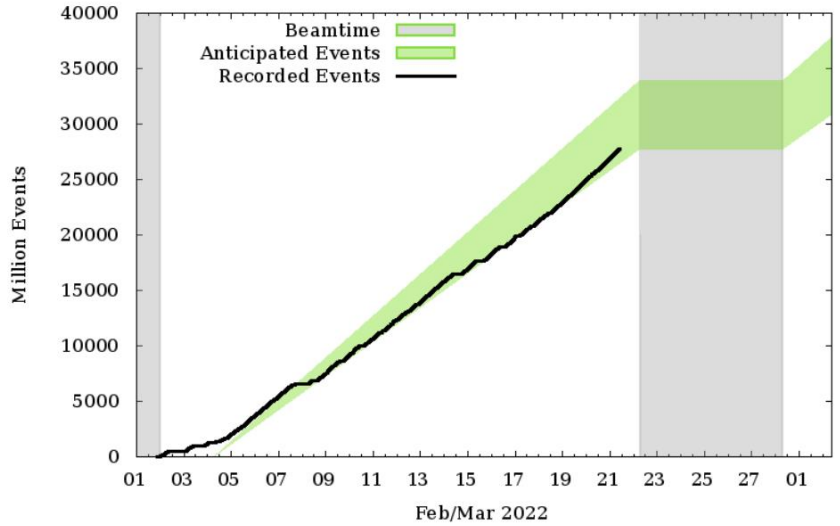
S518 Feb. 2022 (p+p)

- Currently running (until March 9) – in cooperation with PANDA (PANDA HADES MoU)
- New detectors: STS forward tracker stations (PANDA), forward RPC (HADES) photon camera (CBM), inner TOF (FAIR-NRW), LGAD T0 (HADES)
- 42 B events anticipated
- 7 PhD students already participating in beam time

next G-PAC (we hope for ~1 experiment per year)

- Pion-beam experiments (S517)
- Au-Au excitation function (S520)





New HADES members

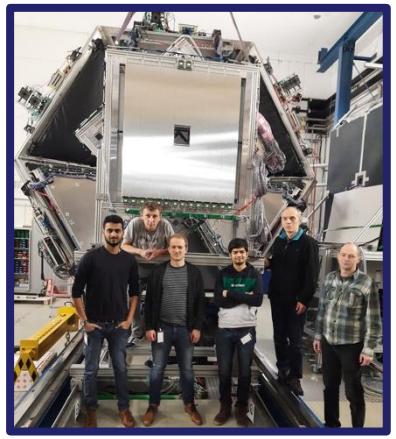
The HADES Phase-0 activity has attracted new members with own funding

- Polish initiative to increase participation in HADES (coordinated by Prof. Salabura)
  - Institute of Nuclear Physics, Polish Academy of Sciences, Cracow (5)
  - AGH University of Science and Technology, Cracow (6)
  - University of Warsaw - Institute of Experimental Physics (3)
  - Warsaw Techical University (8)
- FZJülich (Prof. Ritmans group) – now FAIR-NRW (10)
- Swedish PANDA colleagues (through PANDA.HADES MoU, coord. Prof Schönning)
  - Department of Physics and Astronomy, Uppsala University (5)
  - University of Stockholm
- To come soon: cooperation with NUSTAR-R3B
  - TU Darmstadt
  - MIT

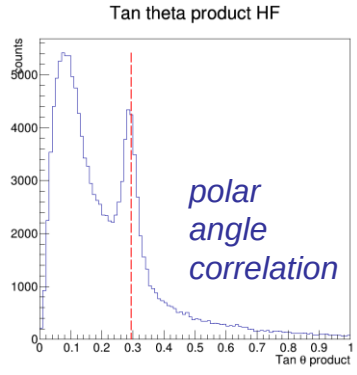
Performance forward tracking stations

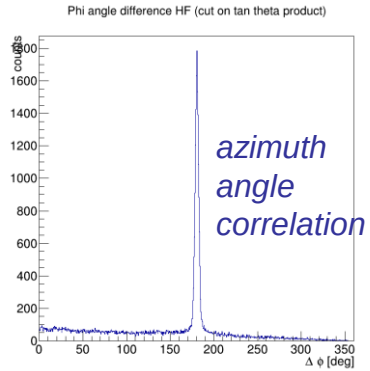
STS 1:
FAIR-NRW
(Jülich) team

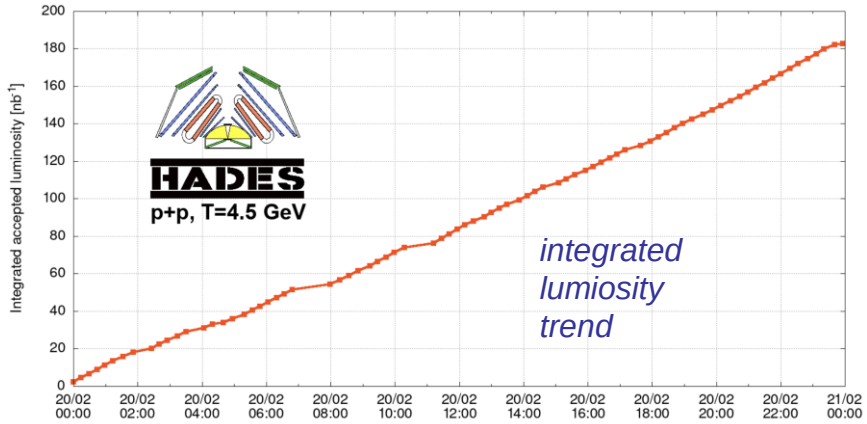
STS 2:
Cracow team
(JU, AGH)



- Precise track reconstruction in forward region
- Online used for luminosity monitoring by identification of elastically scattered protons





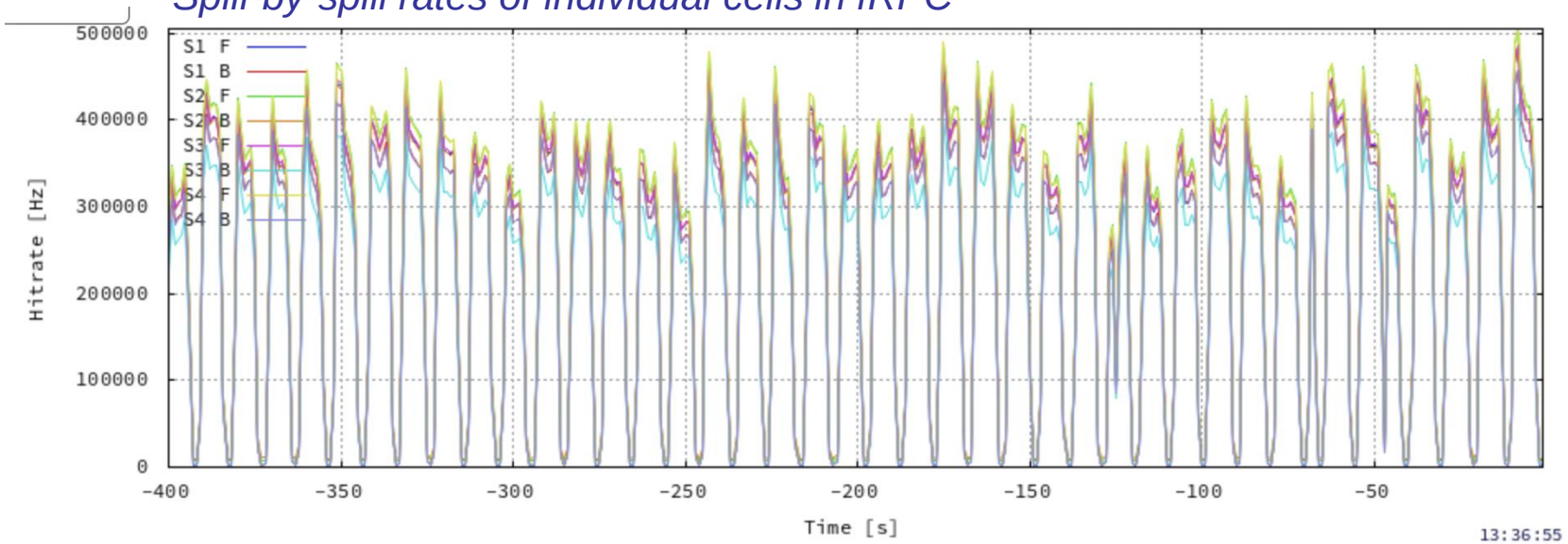


The forward RPC

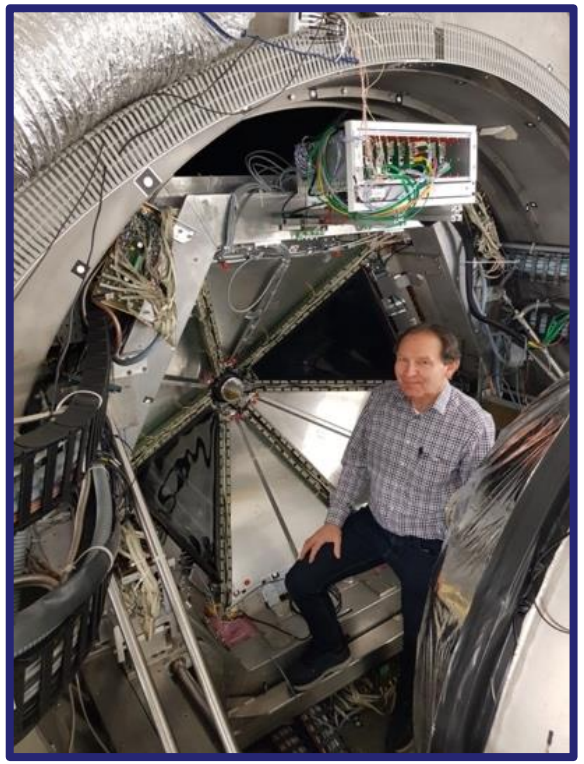
- Precise time-of-flight measuremet at high rates
- Privides particel identification at forward angles
- Bases on technology developed during R&D for neuLAND

fRPC:
Coimbra team (LIP)

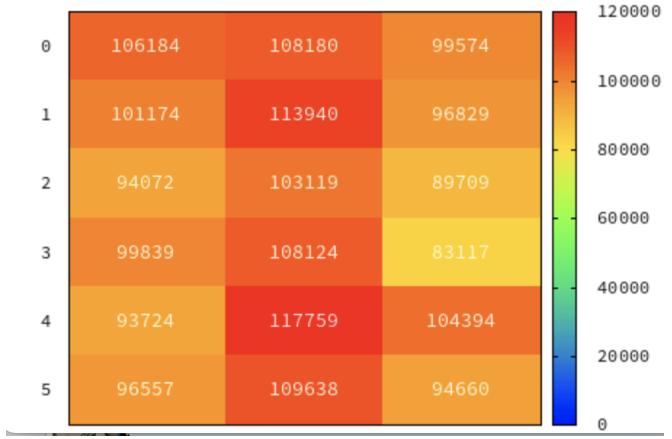
Spill-by-spill rates of individual cells in fRPC



iTOF



- Provides fast timing signals for charged particles entering the HADES tracking stations (MDC)
- 6x3 scintillator paddels read out with photo diodes
- Need to increase trigger purity for low-multiplicity events (PT3)



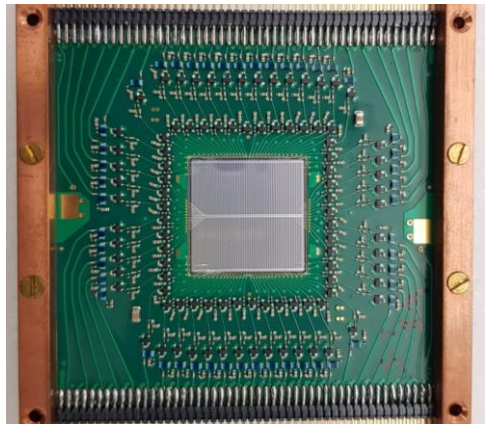
rates per paddle

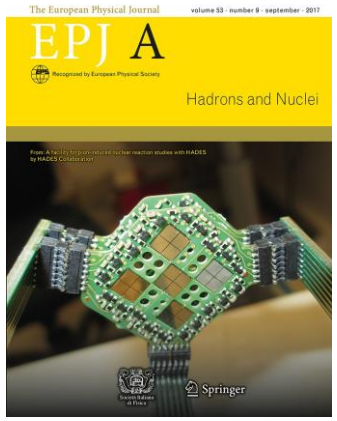
iTOF:
FAIR-NRW
“one man show”

trigger rates

	1	2	3	4	5	6	7	8
Start X in	4670753	3888237	3252213	2914637	5346988	6013231	6523858	6863601
Start Y in	5056478	4698229	4271278	3727032	937630	1416183	2017714	0
Veto in	0	0	0	0	0	0	0	0
TOF in	174870	156024	157602	141842	159392	165641	--	--
RPC in	233583	197970	199671	185190	198336	193601	--	--
Mult out	0	0	0	0	0	0	--	--
PT in	644207	587027	106883	0	1203707	280446	10	486476
PT dsc	644207	9172	106883	0	1203707	280446	10	486476
PT coin	0	0	0	0	0	0	0	0
PT out	0	3531	38710	0	0	0	5	0
Pulser	0	--	MDC Calib.	SHW Calib.	SHW Ped.	Status	--	--
Out								**42248**

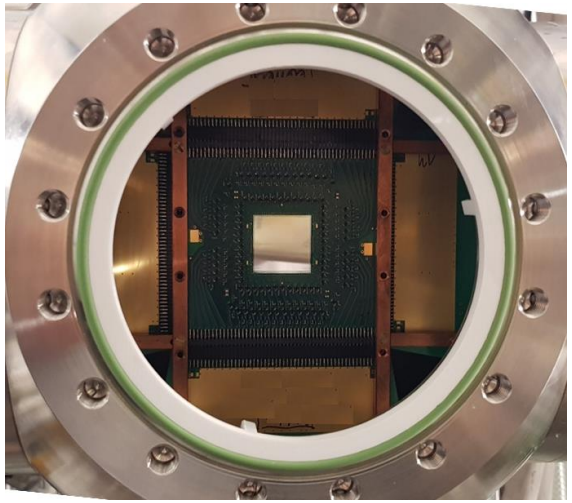
Rad. hard T0 detector based on LGAD



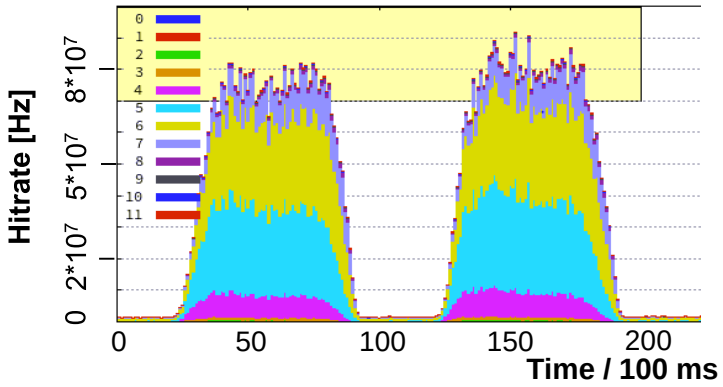


- In-beam detector with high timing precision
- Low-gain avelanche Diode implemented in silicon devices
- Hugh R&D effort worldwide (particle physics)
- So far funded by BMBF
- High rates of up to 10 MHz per channel
- Timing precision < 100 ps

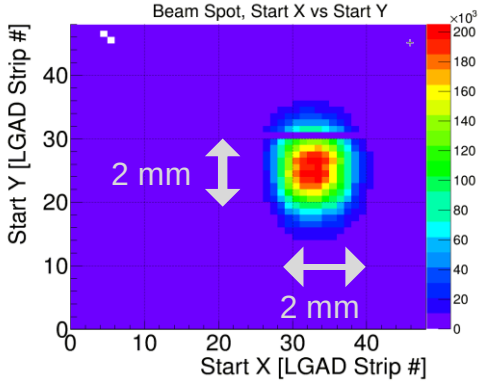
T0 (START):
GSI and
TU Darmstadt



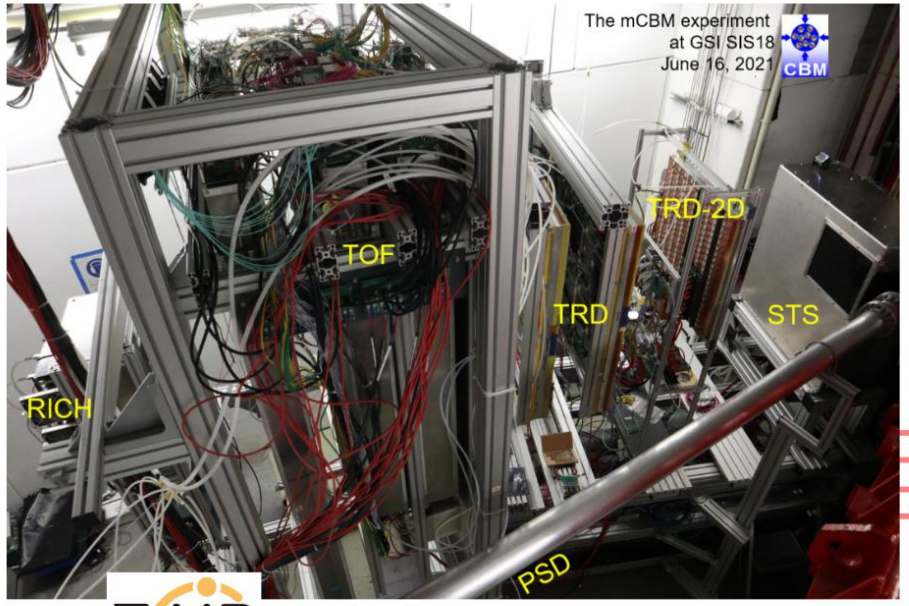
Spill profile
channel added (colors)



Beam spot on T0



The mCBM experiment at SIS18 (July 2021)



optical fibers 50m

DAQ container

CRI (PCIe) @ FLES entry nodes

optical fibers 300 m

FLES processing nodes

TFC (CRI based)

triggerless-streaming FEE **assigning time stamps to hits**

1 m Copper

GBTx

50 m optical

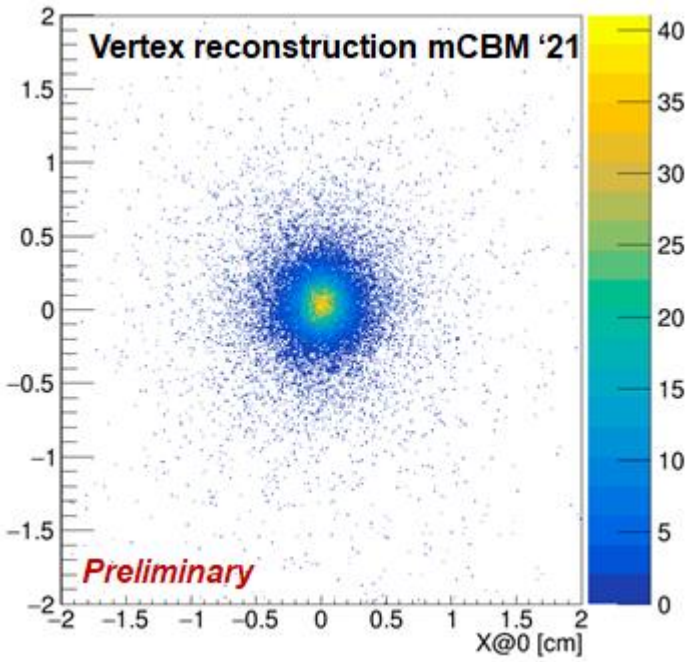
CRI FPGA **µSlice building** FLES entry nodes

300 m optical InfiniBand

Green IT Cube

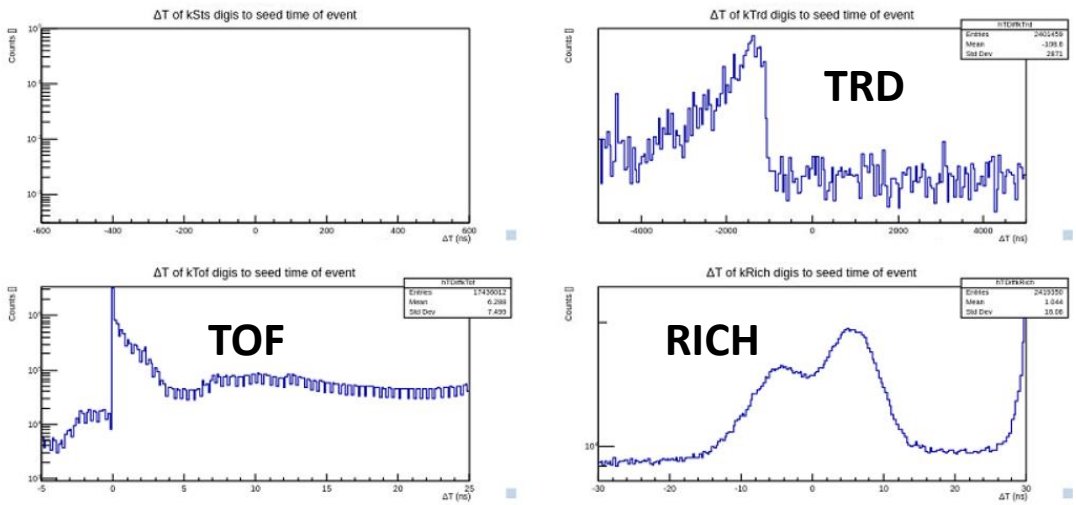
- Timeslice Building
- Event Reconstruction
- Event Selection
- Archiving

mCBM - achievements



July 2021, Run1588
First synchronized CRI data taking
with STS, TRD, TRD2D, TOF, RICH, PSD

O+Ni at T = 2A GeV
1 MHz collision rate,
Archiving rate: 5 TB raw data in 2.4 h
Calibration and alignment in progress



Feb. 2022, Run 1962, Cosmic
First online selection and archiving of events
with TRD, TOF, RICH
Full data processing chain demonstrated

Plan for 2022: high rate detector tests
selection of Λ - candidate events

Plans for 2023 – 2025 (LoI)
Measurement of excitation function of
Λ – and ${}^{3}_{\Lambda}H$ - production

CBM collaboration structure

Collaboration Board
Chair N. Xu (CCNU), Dep. A. Kugler (NPI-CAS)

Junior Representative
A. Mayer-Ahrens (WWU)

Spokesperson
N. Herrmann (UHD), Dep. S. Chattopadhyay (VECC) . V. Ladygin (JINR)

Management Board
ex officio members
C. Höhne (UGI)
C. Schmidt (GSI)
J. Stroth (UFRA, GSI)

Resource Board
J. Eschke (FAIR)

- China — N. Xu (CCNU)
- Czech Rep. — A. Kugler (NPI-CAS)
- Germany — K.Kampert (UWU)
- Hungary — G. Wolf (WRCP)
- India — S. Chattopaghay (VECC)
- Korea — I.-K.Yoo (PNU
- Poland — P.Staszel (UJAG)
- Romania — M. Petrovici (IFIN-HH)
- Russia — A. Akindinov (ITEP)
- Ukraine — V. Putgatch (KINR)
- JINR — V. Ladygin (JINR)

Technical Board
P. Gasik (FAIR)

- Cave — M. Kis (GSI)
- Magnet — P. Senger (GSI)
- MVD — J. Stroth (UFRA, GSI)
- STS — H.R. Schmidt (UTÜB, GSI)
- MUCH — S. Chattopadhyay (VECC)
- RICH — C. Höhne (UGI), K. Kampert (UWU)
- TRD — C. Blume (UFRA)
- TOF — I. Deppner (UHD)
- ECAL — I. Korolko (ITEP)
- PSD — F. Guber (INR)
- DAQ — D. Emschermann (GSI)
- FLES-IN — J. DeCuveland (FIAS)
- BMON — T. Galatyuk (TUDA)

Computing Board
V. Friese (GSI)

- SIM — NN
- EDC — P.A. Loizeau (GSI)
- ODM — J. DeCuveland (FIAS)
- DPF — V. Friese (GSI)
- ALG — S. Gorbunov (GSI)
- OAE — NN
- INF — F. Uhlig (GSI)
- PDB

Physics Board
I. Selyuzhenkov (GSI)

- Hadron — I. Vassiliev (GSI), V. Klochkov (UTÜB), S. Das (BOSE)
- Dilepton — T. Galatyuk (TUDA), P. Bhaduri (VECC)
- C2F — I. Selyuzhenkov (GSI), H. Zbroszczyk (WUT)
- COM — O. Golosov (MEPhI), I. Selyuzhenkov (GSI)

Conference & Editorial Board
H.R. Schmidt (UTÜB, GSI)

Operations
C. Sturm (GSI)

- mCBM — C. Sturm (GSI)

Acronyms

MVD – Micro Vertex Detector
STS – Silicon Tracking System
MUCH – MUon Chambers
RICH – Ring Imaging Cherenkov detector
TRD – Transition Radiation Detector
TOF – Tim Of Flight detector
ECAL – Electromagnetic CALorimeter
DAQ – Data AcQuisition system
FLES- IN – First Level Selector – Input Nodes
BMON – Beam/Monitor Counters

SIM - SIMulation
EDC – Experiment & Detector Control
ODM – Online Data Management
DPF – Data Processing Framework
ALG – ALGorithms
OAE – Offline Analysis Environment
INF – software INFrastructure
PDB – Parameter DataBase
C2F – Correlation, Flow, Fluctuations
COM - COMmon

Full + Associated Member Institutions

- 66 institutes
- 400 full members

New groups admitted in 9/2021
University of Tsukuba (ShinIchi Esumi)
Mainz University (Matthias Schott)

Summary / Conclusion

CBM/HADES scientific program at SIS100 is unique

explore QCD matter at baryon densities up to neutron star core densities

employ high statistics capability

to achieve high-precision of multi-differential observables

to enable rare processes as sensitive probes

CBM day-1 setup allows start of program with significant discovery potential

excitation function of hyperons and light hypernuclei production

excitation function of di-lepton production

CBM/HADES Phase 0 activities targeted towards best use of available instrumentation

CBM – RICH sensors & readout	in HADES at SIS18
CBM – TOF and HPC software	in STAR at RHIC/BNL
CBM – PSD and CBM - STS	in BM@N at Nuclotron/JINR
Integration of all subsystems & FLES	in mCBM at SIS18

Active program needs to be maintained to attract young researchers.

CBM/HADES need the sustained support of all funding agencies for HW and SW projects.